

TECHNICAL BASIS AND BACKGROUND FOR SOIL CLEANUP GUIDELINES BASED ON DIRECT CONTACT

I. OVERVIEW

The purpose of the direct contact soil guidelines computed by the Maine Department of Environmental Protection (DEP) is to identify, for individual hazardous substances, levels which prevent adverse human health effects from occurring as a result of long term exposure to soils but not consumption of underlying groundwater. A quantitative health risk assessment approach based on Maine's *Guidance Manual for Human Health Risk Assessments at Hazardous Substance Sites* (Manual) was utilized. Conservative default exposure factors were selected to ensure protectiveness and exposure to soil was evaluated for both the residential and non residential settings.

The chemicals evaluated were selected based on their frequency of detection at known contaminated sites in Maine and the availability of reliable toxicity information. For each constituent, DEP calculated the level (Exposure Point Concentration) which represents the acceptable level (Hazard Index of 1 for noncarcinogens, and Incremental Lifetime Cancer Risk of 1 in 100,000 for carcinogens) for the individual contaminant. At sites contaminated with multiple compounds, remediation meeting only the guidelines for the individual compounds may result in total site risk above acceptable levels. As stated in the Manual, the total risk from the site must be acceptable for DEP to consider the site "clean".

II. GENERAL METHODS

A. DOSE RESPONSE ASSESSMENT

Data sources for the chronic reference dose (RfD) and carcinogenic potency factor (CPF) were, in order of priority, the U.S. Environmental Protection Agency (EPA) Integrated Risk Information System (IRIS) and the EPA Health Effects Assessment Summary Tables (HEAST). In rare cases other sources, such as other states databases or in consultation with toxicologists, may have been used. These sources have been noted. Where EPA provided only a reference concentration (RfC) or Inhalation Unit Risk (IUR), conversions to RfD or CPF were performed if appropriate according to the formulas in Exhibit 4.2 and 4.3.

B. EXPOSURE ASSESSMENT

Exhibit 3.2 of the Manual lists the potential exposure pathways for both residential and non residential scenarios. In formulating the direct contact soil guidelines, DEP considered the chronic noncarcinogenic exposures and lifetime exposures to potential carcinogens for incidental ingestion of contaminated soil, inhalation of volatile emissions from contaminated soil, inhalation of fugitive dusts from contaminated soil and dermal contact with contaminated soil.

The guidelines were derived with intentionally conservative default exposure factors because several potential pathways were not considered, or in the case of dermal contact, cannot be quantified for most chemicals. It is DEP's expectation that in order to employ less conservative levels, the site must be adequately characterized and a full risk assessment conducted.

The Manual provides formulas to convert all exposures to a dose expressed in units of milligrams of chemical per day adjusted for the body weight of the exposed person (mg chemical /kg BW · day). This Average Daily Dose on a day of exposure is estimated as follows:

$$\text{ADD}_{day} = \frac{\text{EPC} * \text{CR} * \text{ET}}{\text{BW}} \quad (\text{Manual Exhibit 3.6})$$

Where:

ADD <i>day</i>	=	Average Daily Dose, in these guidelines always expressed as units of mg chemical/kg BW · day
EPC	=	Exposure Point Concentration, in these guidelines always expressed as mg chemical/kg soil
CR	=	Contact Rate, for example, 200 mg soil/day for young children
ET	=	Exposure Time, appropriate only when the contact rate is <u>not</u> a daily rate
BW	=	Body Weight, in the guidelines always expressed as kg BW

The formulas used to derive ADD *day* for various media and exposure pathways used in these guidelines are described below. The life stage approach outlined in the Manual (young child, older child, adult) dictates that ADD *day* must be determined for each age group separately.

Next, the ADD *day* is multiplied by the Exposure Frequency to obtain the ADD *chronic*:

$$\text{ADD}_{chronic} = \text{ADD (day)} * \frac{\text{EF}}{\text{DPY}} \quad (\text{Manual Exhibit 3.7})$$

Where	EF	=	Exposure Frequency expressed in Days per Year
	DPY	=	365 Days per year

Note that the exposure frequency term is the ratio of days per year of exposure to the absolute days per year, resulting in a dimensionless ratio. Therefore, the units for ADD *chronic* remain as units of mg chemical/kg BW · day.

The Manual estimates the Hazard Index (HI) for chronic noncarcinogenic effects as the ADD *chronic* divided by the chronic reference dose:

$$HI = \frac{ADD_{chronic}}{RfD_{chronic}} \quad (\text{Manual Exhibit 5.2})$$

By substitution, HI can also be expressed as follows:

$$HI = \frac{EPC * CR * ET}{BW} * \frac{EF}{DPY} \quad RfD$$

The maximum acceptable HI value is 1. Therefore; by inserting a value of 1 for the HI and rearranging the formula, the maximum acceptable EPC for the pathway can be obtained, as follows:

$$EPC = RfD * \frac{BW}{CR * ET} * \frac{DPY}{EF}$$

It should be noted that conversion factors for units of mass, surface area, etc. are often necessary. This will be made explicit below.

Additionally, to evaluate risk of exposure to carcinogens, the *ADD chronic* for each of the 3 life stages defined in the Manual (young child, older child, and adult) must be estimated in order to calculate *ADD life*:

$$ADD_{life} = \frac{[ED_{yc} * ADD_{chronic_{yc}}] + [ED_{oc} * ADD_{chronic_{oc}}] + [ED_a * ADD_{chronic_a}]}{AT} \quad (\text{Manual Exhibit 3.9})$$

Where:

<i>ADD life</i>	=	Average daily dose over a lifetime (mg chemical/kg · day)
<i>ED_{yc}</i>	=	Exposure Duration as Young Child (years)
<i>ED_{oc}</i>	=	Exposure Duration as an Older Child (years)
<i>ED_a</i>	=	Exposure Duration as an Adult (years)
<i>ADD chronic_{yc}</i>	=	Chronic Average daily dose as a Young Child (mg chemical /kg BW · day)
<i>ADD chronic_{oc}</i>	=	Chronic Average daily dose as an Older Child (mg chemical /kg BW · day)
<i>ADD chronic_a</i>	=	Chronic Average daily dose as an Adult (mg chemical /kg BW · day)
<i>AT</i>	=	Averaging Time in years

The Incremental Lifetime Cancer Risk (ILCR) is obtained as follows:

$$ILCR = ADD_{life} * CPF \quad (\text{Manual Exhibit 5.1})$$

Where:

ILCR	=	Incremental Lifetime Cancer Risk (dimensionless, probability)
ADD <i>life</i>	=	Average Daily Dose Averaged over a lifetime (mg chemical /kg BW · day)
CPF	=	Cancer Potency Factor (mg chemical /kg BW · day) ⁻¹

By substitution, the ILCR can be expressed as follows:

$$\text{ILCR} = \frac{[\text{ED}_{\text{yc}} * \text{ADD}_{\text{chronic}_{\text{yc}}}] + [\text{ED}_{\text{oc}} * \text{ADD}_{\text{chronic}_{\text{oc}}}] + [\text{ED}_{\text{a}} * \text{ADD}_{\text{chronic}_{\text{a}}}] * \text{CPF}}{\text{AT}}$$

The maximum acceptable ILCR value is 10⁻⁵. Therefore, by inserting the value of 10⁻⁵ for the ILCR and rearranging the formula the maximum acceptable EPC for the pathway can be obtained, as follows:

$$\text{EPC} = \frac{10^{-5} * \text{AT}}{\text{CPF} * [(\text{ED} * ((\text{CR} * \text{CF}) / \text{BW}) * \text{EF})_{\text{YC}} + (\text{ED} * ((\text{CR} * \text{CF}) / \text{BW}) * \text{EF})_{\text{OC}} + (\text{ED} * ((\text{CR} * \text{CF}) / \text{BW}) * \text{EF})_{\text{A}}]}$$

Where CF = Conversion Factor, for example, 10³ µg/mg

III. DEFAULT EXPOSURE FACTORS AND FORMULA FOR ADD *day*

A. SOIL INGESTION

1. Non Carcinogenic Effects

DEP determined that the most sensitive receptor for non carcinogenic effects based on soil ingestion is the young child, from 1 to <6 years of age, exposed at home. ADD *day* was determined for this age group, using Exhibit 3.16 of the Manual and conservative default exposure factors presented in Manual Exhibit 3.21. For generic cleanup guidelines, DEP considers it appropriate to use the conservative simplifying assumption that all of the soil ingested is contaminated.

For consistency, 3 significant figures were carried through the calculations.

Exhibit 3.16, formula for ADD *day* for ingestion of soil or sediment:

$$\text{ADD}_{\text{day}} = \frac{\text{EPC (mg/kg soil)} * \text{IR (mg soil/day)} * \text{FC} * \text{CF (kg soil/mg soil)}}{\text{BW (kg)}}$$

Where:

EPC	=	Exposure Point Concentration, mg contaminant/kg soil
IR	=	Ingestion Rate, 200 mg soil/day ages 1 to <6 years
FC	=	Fraction Contaminated, 1.0
BW	=	Body Weight, 15 kg ages 1 to <6 years
CF	=	10^{-6} kg soil/mg soil

Exhibit 3.7, formula for *ADD chronic*

$$ADD_{chronic} = ADD_{day} * \frac{EF}{DPY}$$

Where Exposure Frequency (EF) = 143 days per year ages 1 to <6

Note: The figure of 143 days per year is based on 5 days per week for 13 weeks in summer and 3 days per week for 26 weeks of spring & fall.

Exhibit 5.2, formula to estimate chronic Hazard Index

$$HI = \frac{ADD_{chronic}}{RfD}$$

To solve for the acceptable soil level, $HI = 1$ was substituted into the formula in Exhibit 5.2, the default exposure assumptions inserted and the equation rearranged to solve for EPC as follows:

$$EPC \text{ (mg contaminant/kg soil)} = 0.19 \text{ E}+6 \frac{\text{kg BW} \cdot \text{day}}{\text{kg soil}} * \frac{RfD \text{ mg contaminant}}{\text{kg BW} \cdot \text{day}}$$

For non residential (commercial/industrial) exposure scenarios, DEP evaluated exposures for two populations: older children who trespass on site and long term on site workers. Again, to ensure protectiveness, conservative default exposure factors were selected as follows:

IR (Ingestion Rate)	100 mg/day, ages 6-<18 years 50 mg/day, adult
FC (Fraction Contaminated)	1.0 (dimensionless)
BW (Body Weight)	42 kg ages 6-<18 years 70 kg adult
EF (Exposure Frequency)	143 days per year, ages 6-<18 years 250 days per year, adult

To solve for the soil level protective of older children trespassing on site, HI =1 was substituted into the formula in Exhibit 5.2, the appropriate default exposure assumptions listed above inserted and the equation rearranged as follows:

$$\text{EPC (mg contaminant/kg soil)} = 1.07 \text{ E}+6 \frac{\text{kg BW} \cdot \text{day}}{\text{kg soil}} * \text{RfD} \frac{\text{mg contaminant}}{\text{kg BW} \cdot \text{day}}$$

To solve for the soil level protective of adults working on site, HI =1 was substituted into the formula in Exhibit 5.2, the appropriate default exposure assumptions listed above inserted and the equation rearranged as follows:

$$\text{EPC (mg contaminant/kg soil)} = 2.04 \text{ E}+6 \frac{\text{kg BW} \cdot \text{day}}{\text{kg soil}} * \text{RfD} \frac{\text{mg contaminant}}{\text{kg BW} \cdot \text{day}}$$

Table 1 lists guidelines based on incidental ingestion of soil contaminated by noncarcinogens for the residential, trespasser and adult worker scenarios.

2. Carcinogenic Effects

Guidelines for contaminants based on carcinogenic effects are averaged over a 70 year lifetime. In accordance with the Manual, the residential guidelines were based on the conservative assumption that the first 30 years of an individual's lifetime are spent at the site. For consistency, 3 significant figures were carried throughout the calculations. The ADD *chronic* for older children and adults ages 18 to <30 was computed using Exhibits 3.16 and 3.7 (presented above). The additional default exposure assumptions from Exhibit 3.21 are as follows:

Ingestion rate, adult (gardening)	=	100 mg/day
Days exposure, adult	=	78 days per year
Fraction Contaminated	=	1.0 (dimensionless)

Exhibits 3.9 and 5.1 of the Manual outline the process followed to derive the formula for the Exposure Point Concentration (EPC) in mg contaminant per kg soil at an Incremental Lifetime Cancer Risk (ILCR) of 1 in 100,000 (10^{-5}):

Exhibit 3.9, ADD *Life*:

$$\text{ADD life} = \frac{[(\text{ED}_{\text{YC}} * \text{ADD chronic}_{\text{YC}}) + (\text{ED}_{\text{OC}} * \text{ADD chronic}_{\text{OC}}) + (\text{ED}_{\text{A}} * \text{ADD chronic}_{\text{A}})]}{\text{AT}}$$

Where:

ED = Exposure Duration 5 years ages 1 to <6 years
 12 years ages 6 to <18 years
 12 years ages 18<30 years

AT = Averaging Time of 70 years

Exhibit 5.1, formula for ILCR

ICLR = ADD *life* * CPF

Where CPF = Cancer Potency Factor, (mg contaminant/kg BW · day)⁻¹

To solve for the soil level of carcinogens protective of residents the maximum acceptable cancer risk (10⁻⁵) was substituted in the formula in Exhibit 5.1, the appropriate default exposure assumptions listed above were inserted and the equation rearranged as follows:

$$\text{EPC } \frac{\text{mg contaminant}}{\text{kg soil}} = \frac{17.1 (\text{kg BW} \cdot \text{day/kg soil})}{\text{CPF (mg contaminant/kg BW} \cdot \text{day)}^{-1}}$$

For non residential (commercial/industrial) exposure scenarios, DEP evaluated exposures for two populations: older children who trespass on site and long term workers. Additional default exposure values were selected for adult workers of 250 work days per year for 25 years. To ensure protectiveness, trespassers were assumed to visit the site with the same frequency used for residential scenarios, 143 days per year. The fraction of soil ingested assumed to be contaminated was 1.0 (dimensionless) for both scenarios.

To solve for the soil level of carcinogens protective of older children trespassing on site the maximum acceptable cancer risk (10⁻⁵) was substituted into the formula in Exhibit 5.1, the appropriate default exposure assumptions listed above were inserted and the equation rearranged as follows:

$$\text{EPC } \frac{\text{mg contaminant}}{\text{kg soil}} = \frac{62.5 (\text{kg BW} \cdot \text{day/kg soil})}{\text{CPF (mg contaminant/kg BW} \cdot \text{day)}^{-1}}$$

To solve for the soil level of carcinogens protective of adults working on site the maximum acceptable cancer risk (10⁻⁵) was substituted into the formula in Exhibit 5.1, the appropriate default exposure assumptions listed above were inserted and the equation rearranged as follows:

$$\text{EPC } \frac{\text{mg contaminant}}{\text{kg soil}} = \frac{55.6 (\text{kg BW} \cdot \text{day/kg soil})}{\text{CPF (mg contaminant/kg BW} \cdot \text{day)}^{-1}}$$

Table 1 lists guidelines based on incidental ingestion of soil contaminated by carcinogens for the residential, trespasser and adult worker scenarios.

B. INHALATION OF VAPORS FROM CONTAMINATED SOILS

Contaminated soil poses an inhalation risk via vapors and dust. For the residential scenario, this pathway was based on exposure to indoor air, thus the exposure frequency for the residential scenario was set at the default value of 350 days per year and the ages evaluated in the "young child" life stage was broadened to 0 to <6 years, with a body weight of 14 kg. The weight and duration defaults for the other life stages did not change.

1. Non Carcinogenic Effects

In order to derive a dose in mg/kg · day, DEP consulted the Technical Background Document for Soil Screening Level Guidance (EPA, 1996), to obtain the Volatilization Factor (VF) for several chemicals and the formula to derive additional VFs, which were used to derive EPC_a, the exposure point concentration in air:

$$EPC_a = 1/VF * EPC_s$$

Where	EPC _a	=	Exposure Point Concentration in air, mg chemical/m ³ air
	VF	=	Volatilization Factor, m ³ air/kg soil
	EPC _s	=	Exposure Point Concentration in soil, mg chemical/kg soil

Exhibit 3.17 in the Manual presents the formula to convert EPC_a to ADD *day*. Once again, the most sensitive receptor for noncarcinogens was the young child.

$$ADD_{day, young child} = \frac{EPC_a * InhR}{BW}$$

Where	InhR	=	Inhalation rate =	4 m ³ /day for ages 0 to <6
	BW	=	Body Weight =	14 kg for ages 0 to <6

Once ADD *day* was obtained, the procedures described above were followed. For consistency, 3 significant figures were carried through the calculations. To solve for the acceptable soil level, HI = 1 was substituted into the formula shown in Exhibit 5.2 and the equation rearranged as follows:

EPC (mg chemical/kg soil) =

$$\frac{RfD \text{ (mg chemical/kg BW} \cdot \text{day)} * VF \text{ (m}^3\text{/kg soil)}}{0.28 \text{ (m}^3\text{/kg BW day)}}$$

Note: In keeping with the Manual, if only a reference concentration as provided by USEPA could be located, it was converted to a reference dose using the formula shown in Manual Exhibit 4.3, as follows:

$$RfD_i = \frac{RfC * S_{InhR}}{SBW}$$

Where:

$$\begin{aligned} RfD_i &= \text{Reference Dose for Inhalation (mg chemical/kg BW} \cdot \text{day)} \\ RfC &= \text{Reference Concentration (mg chemical/m}^3 \text{ air)} \\ S_{InhR} &= \text{Standard Inhalation Rate (20 m}^3 \text{ air/day)} \\ SBW &= \text{Standard Body Weight (70 kg)} \end{aligned}$$

For non residential exposure scenarios, DEP evaluated exposures for two populations: older children who trespass on site and long term workers. The default exposure factors for inhalation rate and exposure duration are presented in the Manual. Because trespassers will only be on the site for part of the day, DEP assumed that 20% of the volume of air per day was consumed at the site.

For trespassers, the formula for the soil guideline is:

$$EPC \text{ (mg contaminant/kg soil)} =$$

$$\frac{RfD \text{ (mg chemical/kg BW} \cdot \text{day)}}{0.04 \text{ (m}^3 \text{/kg BW} \cdot \text{day)}} * VF \text{ (m}^3 \text{/kg soil)}$$

For adult workers, the formula for the soil guideline is:

$$EPC \text{ (mg contaminant/kg soil)} =$$

$$\frac{RfD \text{ (mg chemical/kg BW} \cdot \text{day)}}{0.21 \text{ (m}^3 \text{/kg BW} \cdot \text{day)}} * VF \text{ (m}^3 \text{/kg soil)}$$

The guidelines based on inhalation of vapors from contaminated soil for the noncarcinogenic effects evaluated are presented in Table 2.

2. Carcinogenic Effects

The additional default exposure assumptions for the residential exposure scenario are as follows:

InhR, Older Children and Adults	=	20 m ³ /day
ED, Exposure Duration	=	6 years ages 0 to <6
		12 years ages 6 to <18
		12 years ages 18<30
AT, Averaging Time	=	70 years

The soil guideline for acceptable residential exposure to vapors released from contaminated soil is computed by substituting 10^{-5} as the ILCR and solving for the EPC:

EPC (mg contaminant/kg soil) =

$$\frac{6.67 \text{ E-5 (kg BW} \cdot \text{day/m}^3 \text{ air)}}{\text{CPF (mg contaminant/kg BW} \cdot \text{day)}^{-1}} * \text{VF (m}^3 \text{ air/kg soil)}$$

For non residential exposure scenarios, DEP evaluated exposures for two populations: older children who trespass on site and adult, long term workers. For adult workers, the exposure frequency provided in the Manual is 250 days per year and the exposure duration is 25 years. To ensure protectiveness, the exposure frequency and duration for trespassers remain unchanged from the residential scenario; however, the daily inhalation rate of 20 m^3 was adjusted by 20%.

The formula derived through substitution of $\text{ILCR} = 10^{-5}$ for trespassers is:

EPC (mg contaminant/kg soil) =

$$\frac{1.4 \text{ E-3 (kg BW} \cdot \text{day/m}^3 \text{ air)}}{\text{CPF (mg contaminant/kg BW} \cdot \text{day)}^{-1}} * \text{VF (m}^3 \text{ air/kg soil)}$$

The formula derived through substitution of $\text{ILCR} = 10^{-5}$ for adult workers is:

EPC (mg contaminant/kg soil) =

$$\frac{1.4 \text{ E-4 (kg BW} \cdot \text{day/m}^3 \text{ air)}}{\text{CPF (mg contaminant/kg BW} \cdot \text{day)}^{-1}} * \text{VF (m}^3 \text{ air/kg soil)}$$

The guidelines based on inhalation of vapors from contaminated soil for the carcinogenic effects evaluated are presented in Table 2.

C. INHALATION OF FUGITIVE DUSTS/

A portion of inhaled fugitive dust can be entrained in mucous and swallowed; this exposure is more appropriately considered as ingestion. The ingested dose can be estimated as follows:

$$F_{\text{ing}} = \text{InhR} * \text{PM}_{10} = 0.44 \text{ mg/day}$$

$$\text{where InhR} = 20 \text{ m}^3 / \text{day}$$

$$\text{PM}_{10} = 0.22 \text{ } \mu\text{g/m}^3$$

By comparison, this value represents 0.9% of the 50 mg soil/day ingested by adult workers, 0.44% of the amount assumed ingested by residents and trespassers and 0.22 % of the amount of

soil ingested by children. The exposure rates for direct absorption of contaminant adsorbed to fugitive dust is calculated using the methods in the Manual.

The Manual bases the EPC for fugitive dusts on the concentration of chemical in air, not the concentration in particulates or the concentration of particulates in air. The residential exposure scenario includes indoor air and particulates with an exposure frequency of 350 days per year.

1. Non Carcinogenic Risks

Exhibit 3.4 presents the formula to convert the concentration of contaminant in soil to a concentration in air:

$$EPC_a \text{ (mg chemical/m}^3 \text{ air)} =$$

$$EPC_s \text{ (mg chemical/kg soil)} \quad * \quad FC \text{ (dimensionless)} \quad * \quad PM_{10} \text{ (}\mu\text{g/m}^3\text{)} \quad * 10E-9 \text{ kgsoil/}\mu\text{g}$$

Where:

EPC_a	=	Exposure Point Concentration of Chemical in Air, mg chemical/m ³ air
EPC_s	=	Exposure Point Concentration of chemical in soil, mg chemical/kg soil
FC	=	fraction contaminated, assumed to be 1.0, dimensionless
PM_{10}	=	concentration of respirable particles in air, default for chronic exposures of 22 $\mu\text{g/m}^3$

EPC_a was then used to calculate the ADD *day* for this scenario using the formula presented in Exhibit 3.17 and assuming $FC = 1$, as follows:

$$ADD \text{ day} =$$

$$\frac{EPC_a \text{ (mg chemical/m}^3 \text{ air)}}{BW \text{ (kg)}} * \frac{InhR \text{ (m}^3 \text{ air/day)}}{}$$

DEP discovered through several iterations of the calculations for this exposure, that due to the larger inhalation rate older children were the most sensitive group. The default exposure factors used were:

$$\begin{aligned} InhR &= 20 \text{ m}^3/\text{day} \\ BW &= 42 \text{ kg} \end{aligned}$$

ADD *chronic* for this age group was then calculated based on an exposure duration of 350 days per year. To solve for an acceptable soil level, $HI = 1$ was substituted into the formula in Exhibit 5.2 and the equation rearranged as follows:

$$EPC \text{ (mg /kg soil)} =$$

Rfd (mg chemical/kg BW · day)

10.1 E-9 (kg soil/kg BW · day)

For the trespasser (commercial/industrial) scenario, the exposure duration was lowered to 143 days per year and 20% of the air volume was assumed to be from the site (i.e., 4 m³/day). The formula for the soil guideline is as follows:

EPC (mg/ kg soil) =

Rfd (mg chemical/kg BW · day)

0.82 E-9 (kg soil/kg BW · day)

For adult workers, the inhalation rate of 20 m³/day was used with an exposure frequency of 250 days per year and an exposure duration of 25 years. The soil guideline is as follows:

EPC (mg/ kg soil) =

Rfd (mg chemical/kg BW · day)

4.3 E-9 (kg soil/kg BW · day)

The guidelines for noncarcinogenic effects based on inhalation of fugitive dusts for the contaminants evaluated are presented in Table 3.

2. Carcinogenic Risks

Similar methods were used to derive the following formulas for soil guidelines:

Residential:

EPC (mg chemical/ kg soil) =

0.3 E-4 (kg BW · day/kg soil)

CPF (mg chemical/kg BW · day)⁻¹

Trespasser:

EPC (mg chemical/ kg soil) =

7.14 E-4 (kg BW · day/kg soil)

CPF (mg chemical/kg BW · day)⁻¹

Adult Worker:

EPC (mg chemical/ kg soil) =

$$\frac{0.67 \text{ E-4 (kg BW} \cdot \text{day/kg soil)}}{\text{CPF (mg chemical/kg BW} \cdot \text{day)}^{-1}}$$

The guidelines based on carcinogenic effects from inhalation of fugitive dusts for the contaminants evaluated are presented in Table 3.

D. DERMAL CONTACT PATHWAY

Following both EPA and DEP risk assessment guidance, quantitative estimates of risk due to dermal contact with soil are based on the fraction of the contaminant absorbed through the skin. Currently, absorption values are only available for 3 substances. DEP computed cleanup levels for cadmium based on non carcinogenic effects, and PCBs for carcinogenic effects. Because risk is evaluated from the internal amount of chemical, toxicity factors generated from potential doses must be adjusted.

1. Default Assumptions for Skin surface Area

The Manual provides default values for the skin surface area of young children, older children and adults; defaults for the exposure frequency and suggestions (Exhibit 3.19) for the percentage of total surface area exposed during certain activities and weather conditions. In order to incorporate conservative values and simplify the arithmetic, DEP made several assumptions and derived weighted averages of exposed skin surface area.

a. Young Children, ages 1 to <6

Skin Surface Area	=	0.53 m ²	(Exhibit 3.21)
Fraction Skin Area Exposed, Cool Weather	=	0.21	(Exhibit 3.19)
Fraction Skin Area Exposed, Warm Weather	=	0.43	(Exhibit 3.19)
Exposure Frequency, Spring and Fall	=	78 days/yr	(Exhibit 3.20)
Exposure Frequency, Summer	=	65 days/yr	(Exhibit 3.20)

$$\text{Area exposed in summer:} = 0.53 \text{ m}^2 \cdot 0.43 = 0.23 \text{ m}^2 \text{ for 78 days per year}$$

$$\text{Area exposed in spring and fall} = 0.53 \text{ m}^2 \cdot 0.21 = 0.11 \text{ m}^2 \text{ for 65 days per year}$$

$$\text{Weighted average} = 0.18 \text{ m}^2$$

b. Older Children, ages 6 to <18

Skin Surface Area	=	1.31 m ²	(Exhibit 3.21)
Fraction Exposed, Cool Weather	=	0.15	(Exhibit 3.19)
Fraction Exposed, Warm Weather	=	0.40	(Exhibit 3.19)
Exposure Frequency, Spring and Fall	=	78 days/yr	(Exhibit 3.20)
Exposure Frequency, Summer	=	65 days/yr	(Exhibit 3.20)

Area exposed in summer: $= 1.31 \text{ m}^2 \cdot 0.40 = 0.54 \text{ m}^2$ for 78 days

Area exposed in spring and fall $= 1.31 \text{ m}^2 \cdot 0.15 = 0.20 \text{ m}^2$ for 65 days

Weighted average $= 0.38 \text{ m}^2$

c. Adult, ages 18 to 30

Skin Surface Area	=	1.82 m ²	(Exhibit 3.21)
Fraction Exposed, Cool Weather	=	0.13	(Exhibit 3.19)
Fraction Exposed, Warm Weather	=	0.38	(Exhibit 3.19)
Fraction Exposed, Heavy Outdoor Work, Warm Weather, Adult Male	=	0.63	(Exhibit 3.19)
Exposure Frequency, Spring and Summer	=	78 days/yr	(Exhibit 3.20)
Area exposed in summer (light work):	=	1.82 m ² · 0.13 = 0.24 m ²	for 39 days
Area exposed in summer (heavy work)	=	1.82 m ² · 0.38 = 0.69 m ²	for 19 days
Area exposed in spring and fall	=	1.82 m ² · 0.63 = 1.15 m ²	for 20 days
Weighted Average	=	0.58 m ²	

2. Cadmium, Non Carcinogenic Effects

a. Adjusted Reference Dose

Based on discussions with DHS, 2.5% absorption was selected as a reasonable conservative figure. The RfD of 5 E-4 (Potential Dose) should be adjusted based on Exhibit 4.6, to obtain the Internal RfD as follows:

$$\text{RfD (Internal)} = \text{RfD (Potential)} \cdot \text{ABS}$$

$$\text{RfD (Internal)} = 5 \text{ E-4} * 0.025$$

$$\text{RfD (Internal)} = 5 \text{ E-6}$$

b. Calculate Exposure Point Concentration at Hazard Index of 1, Residential Scenario

According to EPA's Dermal Guidance document, the Absorbed Fraction (ABS) for cadmium is 0.1-1%.

Exhibit 3.20, Add *day*, *Young Child*

ADD *day* (mg chemical/ kg BW · day) =

$$\frac{\text{EPC} * (\text{AR}) * \text{FC} * \text{FA} * \text{SA} * \text{FE} * 10^{-6} \text{ (kg soil/mg soil)} * 10^4 \text{ (cm}^2 \text{ skin/m}^2 \text{ skin)}}{\text{BW}}$$

Where:

AR = Adherence Rate of Soil or Sediment to Skin, the default value of
1.0 mg soil/cm² skin · day
FC = Fraction Contaminated, Assumed to equal 1, dimensionless
FA = Fraction Absorbed, Assume Conservative 1%, dimensionless
SA = Skin Area, use weighted average of 0.18 m² (see part a, above) for young child
FE = Fraction Exposed, incorporated into SA (see part a, above)

$$\text{ADD day} = 1.2\text{E-}6 \text{ (kg soil/kg BW} \cdot \text{day)} \quad * \quad \text{EPC mg cadmium/kg soil}$$

Once ADD *day* for dermal contact was computed, the steps outlined previously, employing the default factors already discussed, were followed, yielding, for residential exposures:

$$\text{EPC} = 2.7 \frac{\text{mg cadmium}}{\text{kg soil}} \quad \text{Based on 1\% Absorbed}$$

For commercial/industrial exposures the additional default values for "older children" trespassing are:

$$\begin{aligned} \text{SA} &= 0.38 \text{ m}^2 \\ \text{BW} &= 42 \text{ kg} \\ \text{EF} &= 143 \text{ days per year} \end{aligned}$$

The EPC which results in the maximum acceptable HI of 1 is:

$$\text{EPC} = 3.5 \frac{\text{mg cadmium}}{\text{kg soil}}$$

For adult workers, commercial/industrial exposure, the default values are as follows:

$$\begin{aligned} \text{SA} &= 0.58 \text{ m}^2 \\ \text{BW} &= 70 \text{ kg} \\ \text{EF} &= 250 \text{ days per year} \end{aligned}$$

The EPC which results in the maximum acceptable HI of 1 is:

$$\text{EPC} = 2.3 \frac{\text{mg cadmium}}{\text{kg soil}}$$

Assuming 0.1% absorption from soil, the exposure point concentrations are as follows:

$$\text{EPC} = 27 \frac{\text{mg cadmium}}{\text{kg soil}} \quad \text{Residential (Young Child)}$$

$$\text{EPC} = 35 \frac{\text{mg cadmium}}{\text{kg soil}} \quad \text{Trespasser (Older Child)}$$

$$\text{EPC} = 23 \frac{\text{mg cadmium}}{\text{kg soil}} \quad \text{Adult Worker}$$

3. PCB Contaminated Soil, Carcinogenic Risk of Dermal Contact

DEP consulted with DHS regarding the absorption efficiency of PCB in corn oil. 75% was determined to be a reasonable number. The CPF of 2.2 mg PCB/kg BW · day (Potential Dose) should be adjusted based on Exhibit 4.6, to obtain the Internal CPF for 75% ABS as follows:

$$\text{CPF (Internal)} = \frac{\text{CPF (Potential)}}{\text{ABS}} =$$

$$\frac{2.2 (\text{mg PCB/kg BW} \cdot \text{day})^{-1}}{0.75} =$$

$$2.93 (\text{mg PCB/kg BW} \cdot \text{day})^{-1}$$

According to EPA's Dermal Guidance document, the Absorbed Fraction (ABS) for PCB is 0.6 - 6%.

Assuming 6% absorption efficiency from soil, the maximum acceptable residential exposure level is as follows:

$$\text{EPC} = 4.8 \frac{\text{mg PCB}}{\text{kg soil}}$$

For commercial/industrial exposures the maximum acceptable levels are as follows:

For older children who trespass on site:

$$\text{EPC} = 8.5 \frac{\text{mg PCB}}{\text{kg soil}}$$

For adult workers

$$\text{EPC} = 18.9 \frac{\text{mg PCB}}{\text{kg soil}}$$

kg soil

Assuming the ABS is 0.6% the maximum acceptable level for residential exposure is as follows:

$$\text{EPC} = 48 \frac{\text{mg PCB}}{\text{kg soil}}$$

For commercial/industrial exposures the maximum acceptable levels are as follows:

For older children who trespass on site:

$$\text{EPC} = 85 \frac{\text{mg PCB}}{\text{kg soil}}$$

For adult workers

$$\text{EPC} = 189 \frac{\text{mg PCB}}{\text{kg soil}}$$